# Ultrasonic generation by pulsed UV lasers

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**UU4. Nondestructive determination of ultrasonic velocity and absorption in thin dielectrics by laser-induced pressure pulses.** J. E. West (Acoustics Research Department, AT&T Bell Laboratories, Murray Hill, NJ 07974), G. M. Sessler, and R. Gerhard-Multhaupt (Technical University Darmstadt, Darmstadt, West Germany)

The laser-induced presure pulse (LIPP) generation of acoustic impulses in the 0.5-ns range allows the measurement of ultrasonic velocity and absorption in thin dielectrics in the 0.2- to 1-GHz range. This optoacoustic method generates ultrasonic pulses by thermoelastic effects and ablation due to absorption of 70-ps laser-light pulses in an opaque coupling layer deposited on one of the sample surfaces. Detection of the acoustic pulses is possible by using electrically charged or piezoelectric samples which yield electrode signals upon transit of the pulse. The sound velocity and absorption is determined from the relative delays and spectra, respectively, as the pulse is reflected from the sample surfaces. Multiple LIPP by splitting the laser beam into two time (or more) components and delaying one component relative to the other by a time $T$ results in a boost of the spectrum at the frequency $f = 1/T$. Measurements on several polymers with this technique gives sound speed close to the values determined for the bulk material and attenuation coefficients that rise almost linearly with frequency in the range 0.2–1 GHz.

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**UU5. Optoacoustic effect in SF$_6$.** Manaf Ali and Henry E. Bass (Physical Acoustics Research Group, The University of Mississippi, University, MS 38677)

Short pulses ($\sim 1\ \mu$s) of $10.6\text{-}\mu$ radiation from a CO$_2$ laser have been used to generate optoacoustic pulses in gaseous SF$_6$. The optical path length for $10.6\text{-}\mu$ radiation in SF$_6$ is very short at intermediate pressures ($\sim 1$ Torr) so a strong acoustic pulse is generated which travels in the direction of the incident laser beam (in addition to cylindrical expansion). As the gas pressure is decreased, the optical path length increases resulting in an acoustic pulse with a shape dominated by collisional transfer in SF$_6$. As the pressure is lowered further ($\sim 200$ mTorr), thermal conduction to the test cell walls and spontaneous radiation by the excited gas become important. As these mechanisms begin to compete with slow collisional energy transfer processes, the optoacoustic signal changes in sign. A microscopic description of the behavior will be offered. [Work supported by ONR.]

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**UU6. Ultrasonic generation by pulsed UV lasers.** D. A. Hutchins (Physics Department, Queen's University, Kingston, Ontario, Canada K7L 3N6)

A Q-switched, frequency doubled ruby laser has been used to generate ultrasonic transients in both metals and water. The laser source delivered multimode pulses, of 30-ns duration and energy $<200$ mJ, at a wavelength of 347 nm in the UV. Displacements generated in metal plates were detected by wideband capacitance transducers, and compared to wave propagation theory. Thermoelastic, ablative, and modified surface sources were examined, and a good correlation between experiment and theory obtained. In addition, wideband directivity patterns in aluminum were obtained for the thermoelastic source. Thermal generation in water with a cylindrical geometry was also examined, and the expected dipolar pressure transients recorded. It was shown that their duration was a function of the multimode laser beam diameter over the 1.5- to 4-mm range.

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**UU7. Optically stimulated sound from gas bubbles in water: A novel optoacoustic mechanism.** Bruce T. Unger and Philip L. Marston (Department of Physics, Washington State University, Pullman, WA 99164)

We detected high-frequency sound radiated by individual gas bubbles in response to modulated green light from an argon-ion laser. The bubbles were in clear water and were attached to a needle. Their radii were typically less than 100 $\mu$m. The sound radiated in response to single light pulses, of duration $\simeq 10\ \mu$s and power $\simeq 2$ W, exhibits the ringing of the bubble's monopole resonance. The resonance frequency $f_R$ was found by Fourier transforming this signature; typical values were 30 kHz. Bubbles were subsequently illuminated by bursts of pulses with a frequency $f \simeq f_R$. The resulting sound was characterized by an initial buildup of its amplitude. The mechanism for driving the monopole oscillations appears to be the modulated *optical* radiation pressure on the bubble's surface rather than thermal expansion. Related experiments on the optical levitation of bubbles in water and the emission of sound from dyed drops in water will be discussed. [Work supported by ONR.]

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**UU8. Achievement of substantially higher source levels for airborne-laser-induced underwater sound.** Allan D. Pierce and Hsiao-an Hsieh (Georgia Institute of Technology, Atlanta, GA 30332)

A properly designed airborne laser system can generate a spatially periodic heating pattern (of length $L$ and periodicity $L/n$) that moves with supersonic speed $V$ over the water surface; such creates an $n$-cycle toneburst radiating downward at an angle $\theta = \cos^{-1}(c/V)$ with the horizontal, the sound having wavelength $\lambda = (L/n)\cos\theta$ and frequency $f = c/\lambda$. Analysis is developed for when the laser deposits power $P$ over time $T$, such that the heating pattern moves a net distance $VT$ that is much larger than $L$. Calculations of the farfield radiation $[r \gg (cT)^2/\lambda]$ can yield a peak value of acoustic pressure times radial distance that is approximately $fT/n$ times larger than what results for circumstances studied by Muir, Culbertson, and Clynch [J. Acoust. Soc. Am. **59**, 735–743 (1976)]. Thus, if $f$ is 10 kHz, $T$ is 0.1 s, and $n$ is 10, the source level will be 40 dB higher. The analysis assumes the laser heating penetration depth is somewhat larger than $\lambda/\sin 2\theta$, but this should ordinarily be well satisfied, especially if blue-green light is used. At a range of 10 km, one is typically still within the Fresnel regime; the theory estimates the peak pressure to be of the order of 0.2 Pa when the power $P$ is 100 kW. It is argued that, even with the limitations of existing laser technology, it should be feasible to develop an airborne laser system that will create detectable sound at locations of will at ranges up to 10 km or greater. [Work supported by ONR.]